DOCUMENT RESUME

ED 049 061 SE 011 050

AUTHOR Shah, Sair Ali
TITLE Selected Topological Concepts Taught to Children, Ages Six to Nine.
INSTITUTION Georgia Univ., Athens.
PUB DATE 71
NOTE 7p.; Paper presented at the Annual Meeting of the American Educational Research Association (February 4-7, 1971, New York City, N.Y.)

EDRS PRICE EDRS Price MF-$0.65 HC-$3.29
DESCRIPTORS *Elementary School Mathematics, Grade 1, Grade 2, Grade 3, *Instruction, *Manipulative Materials, *Mathematical Concepts, *Topology

ABSTRACT

The research reported dealt with the ability of first, second, and third grade students to understand the topological concepts of solids, sheets, lines, networks, and of order and betweenness. The concepts were presented through the use of manipulative materials. The instruction was conducted by the regular teachers for a period of three weeks after which test items in workbooks completed by the students, were used for obtaining data. The achievement of each class on each item was tabulated, and differences in performance are discussed. The author concludes that the material presented seems suitable for children in the age range studied. (JG)

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Selected Topological Concepts Taught to Children, Ages Six to Nine

Sair Ali Shah, University of Georgia, 1971

Introduction

The reactions of some children in grades one through three were obtained, to some concepts in "Intuitive Topology," when three teachers in Georgia taught them a series of lessons, over a period of three weeks. An assessment of performances was made from workbooks provided for the children and it was found that a reasonable standard of attainment was achieved.

Mathematical Content Taught

1. Some invariant properties of an object under the operations of bending and stretching, without cutting or joining. This is similar to a body undergoing "elastic motion" and observing the properties, which remained the same. These properties may be considered as some topological properties of an object. Here we considered the topological equivalences of (a) solids, (b) sheets, (c) "lines" and "networks".
2. We also included: Order and Betweenness, which was illustrated by "order' of objects on a string."

Psychological Bases for the Study

1. We used the idea of "proceeding from the concrete to the abstract." Children were provided with kits, which contained: four ounces of plastic clay, ten colored beads and six pieces of toy-pipe cleaners. The material was used by the children for making models and comparing them for their invariant features (that is, features which remained the same) after bending or stretching without cutting or joining.
2. Piaget's idea of Reversibility, was used as a basis for the activities provided. Children were encouraged to carry out the operation of 'bending and stretching without cutting or joining'. These exercises provided 'movement of thinking' at the concrete level. Opportunities at the abstract level were provided in the workbook.
3. Piaget's idea of conservation was used as the basis for obtaining the invariant features of an object under the operation of 'bending and stretching without cutting or joining. The child had to consider the features, which were conserved under the operation.

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Procedure

1. Samples: (a) three teachers at the same school taught the lessons. One taught the grade one, another the grade two, and the next the grade three class. All three teachers were receptive to the ideas of the content and cooperated greatly in using the material with the children. (b) the sample of eighty-eight(88) pupils were within the age range six to nine years. They were distributed as follows: 29 in grade 1 (6+), 29 in grade 2 (7+) and 30 in grade 3 (8+).

2. Teaching the Content

   A teacher's guide was prepared for assisting with instruction. The teachers were given a forty-five minute session by the author, on the content and technique of teaching to be used. The general outline of the technique of teaching had the following stages:

   I. Free play with material from children's kit. Let them make models.
   II. Comparison of models for common features.
   III. Look at pictures in workbook and compare them for common features.
   IV. Ask questions to direct attention to common features of models.

   The workbook provided numerous exercises which the children worked on.

3. Instrument for Obtaining Estimates of Achievement

   Some of the exercises in the workbook were tests. We analyzed the responses in the workbooks, but scores were obtained only for the test exercises.

   The material in the workbooks can be broadly classified into two areas: (a) exercises to find out what criteria children of this experiment used for comparing the given pictures, (b) exercises to find out if they can 'match' objects with common features (or elements) after bending or stretching without cutting or joining.

   The invariant features included in the pictures given in the exercises were: (a) objects without holes, (b) objects with the same number of holes, (c) networks with the same distribution of beads and strings, (d) beads in the same order on two or more strings, (e) closed paths, (f) open paths.

Activities and Results

I. During "free play" with the material of the kit some of the models made by the children were:

1. For solids, they made (a) animals - dogs, cats, rabbits - all with four legs, (b) doughnuts, car tires, rings(they were asked to make things with one hole).
2. For 'sheets' they were told to make a flat sheet with the plastic clay, and then make things with it by bending and stretching it. They made. cookies, plates, bowls, and hats.
3. For 'lines' they were asked to bend their toy pipe cleaners and make letters. They made the letters. C, S, N, Z.
4. For "networks" they used beads for joining pieces of 'pipe cleaners'. Beads were also placed at the free ends of the pipe cleaners.
5. For order of things on a string, they placed four or five beads, each of a different color on a 'pipe cleaner.' The pipe cleaner was then bent, and the order of the beads were compared by observing which bead followed each other.

The above activities, which were performed with concrete material were satisfactorily done, and children discovered without difficulty, the common features of two models. For example. a dog and a cat each has four legs; a plate and a bowl are both made from a sheet; the letters C and S are made by bending one piece of wire; two similar networks have the same number of beads and strings; the order of the beads on a string, was the same, in spite of bending the string.

II. The next activity was that the children were given pictures to be compared. Here it was expected that they will use the invariant features for explaining how the pictures are the same. Estimates of their performances were obtained from their workbooks. Children did find out what these features were and used them. The features were: (a) objects without holes, (b) objects with the same number of holes, (c) networks with the same distribution of beads and strings, (d) beads in the same order in two or more strings, (e) closed paths, (f) open paths.

Other criteria children used for comparison were: shape, size, smoothness, joined, not joined, twisted.

III. Responses to test items(see appendix) were obtained here. The areas covered were:

(a) Comparing objects for common features, after bending and stretching, without cutting or joining. These included: solids, sheets, and wires. Items 1 to 6 inclusive of the test covered this area.

(b) Matching networks with the same number of beads and segments. This was item 7 of the test.

(c) Testing Order and Betweenness, which was covered in item 8 of the test.

Percentages of correct responses were obtained for each of the different test areas as shown below.

Sample: Gd. I = 29, Gd. II = 29, Gd. III = 30

ITEMS ON TEST	PERCENT GAINED BY Gd. I	II	III
I. Bending and Stretching without cutting or joining of: (a) Solids			
Item 1 (See test in Appendix)	58	71	97
Item 2	61	69	71
Item 3	81	33	77
Item 4	52	27	71
(b) Sheets			
Item 5	81	71	87
(c) Wire			
Item 6	68	71	80
II. Networks. Item 7	37	68	97
III. Order and Betweenness. Item 8	52	74	79

Items 1,2,3,4 covered exercises on the topological equivalent of solids, using number of holes as the criterion. On the whole more than fifty percent of the children, except in certain cases of the grade 2 class, gained scores of 50 percent and more. If we consider 50 percent as our level of satisfactory performance, then the responses were reasonable.

Item 5, which involved the bending and stretching of a sheet was used to estimate the topological equivalence of sheets. The percentage ranged from 71 for grade 2, to 87 for grade 3. Grade 1 percent was 81. These were well over our criterion level.

Item 6 was used for the topological equivalence of wires or segments. The percentages ranged from 68 to 80, which were above the criterion level.

Item 7 on the topological equivalence of networks had percentages: 37 for grade 1, 68 for grade 2, and 97 for grade 3. Grades 2 and 3 were above the criterion level, but grade 1 was not.

Item 8 on Order and Betweenness had percentages. 52 for grade 1, 74 for grade 2, and 79 for grade 3. These were above the criterion level.

Discussion

Among the several variables affecting the scores, were: teacher competence; time spent by children on the material; and understanding of material, which involves reading competence of children and understanding of mathematical concepts.

With respect to teacher competence, a teacher's guide was provided and a forty-five minute orientation session was given. Though the teachers expressed understanding of the material, it was felt that since the topic was new, they would have felt more confident, if they had a course on "intuitive topology."

Concerning the time spent on the program by the children, Grade III had ten half-hour sessions. Their performance was satisfactory. The Grade II class spent fifteen twenty minute sessions. Their scores were the lowest in many cases of the three grades and this may be because of the shorter sessions. Another factor, which contributed to the low scores of Grade II, was the high rate of absentism. Grade I spent fifteen half-hour sessions and in some cases gave better performances than the Grade II class.

For understanding of the material, some of the reading involved was beyond the Grade I level. Thus this affected the scores. The teacher of the Grade I class explained that the oral responses of her class were better than their written answers. The scores of the Grade II class were also affected by the reading involved. They scored better on the non-verbal items.

On the scores themselves, using the criterion level of obtaining a score of at least fifty percent on each exercise, the distribution of all the grades except in a very few cases, were satisfactory.

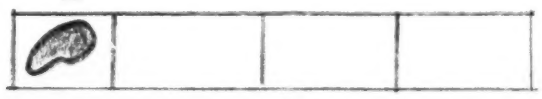
From the above we conjecture that the material, which was prepared by using some psychological bases, seems suitable for children in the age range six to nine years.

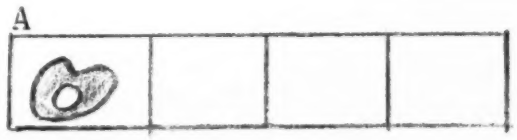
References:

1. Walter Lietzmann, Visual Topology, American Elseview Publishing Company Inc. N.Y. 1965.
2. B.H. Arnold, Intuitive Concepts in Elementary Topology, Prentice-Hall, 1963.
3. Some Lessons in Mathematics, Cambridge University Press.
4. Wolfgang Franz, General Topology, Fred. Ungar. Publishing Co. N.Y.

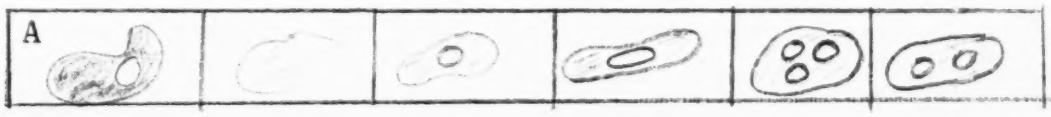
APPENDIX I TEST ITEMS

1. Draw different things which we can make from picture A by bending and stretching without cutting or joining.

a) A 

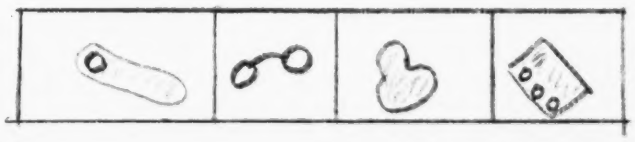
b) A 

2. Draw a mark around the things which we can make from picture A by bending or stretching without cutting or joining.

A 

3. Match the one in A to the one in B which you can get by bending or stretching without cutting or joining.

A

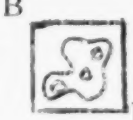
B 

4. Can you get picture B from picture A by bending or stretching without cutting or joining? Put a ring around: yes, no, or I don't know.

A B

yes
no
I don't know

A

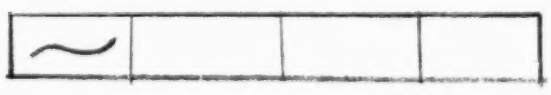
B 

yes
no
I don't know

5. Draw a line from picture A to all the pictures which you can make by bending or stretching but not cutting or joining.

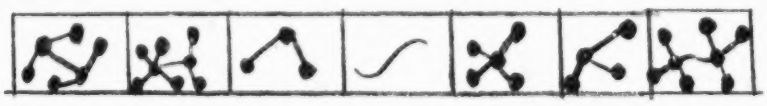
A

6. Draw three things which you can make by bending or stretching picture A, but not cutting or joining.

A 

A

7. Match the pictures which are the same from the two sets.



8. Draw the missing things to make all of these pictures look the same as picture A.

A